

**EFFECT OF SIZE PARTICLE ON PALM OIL WASTE FOR PRODUCTION
OF BIO OIL THROUGH BATCH PYROLYSIS PROCESS**

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ABSTRACT

The production of bio oil from the pyrolysis of palm oil waste (PKS and EFB) has been studied using a small lab scale pyrolysis unit. The effects of sample preparation (particle size) of the sample on the product yields and compositions were investigated. The effect of sample preparation influence the yield of the bio oil for the sample (EFB and PKS). The highest bio oil yield of PKS was obtained at 400 °C at particle size less than 5mm. For EFB, particle size (length) 5 mm -10 mm of EFB shows the higher yield of bio oil. The various characteristics of the bio oil are accomplished under these conditions and identified by the preliminary experiment conducted by using the thermo gravimetric analyzer (TGA) to determine volatility, ash content, moisture and fixed carbon. The functional groups of the product which is bio oil are identified by using fourier transform infrared spectrometer (FTIR). The chemical characterization studies showed that the bio oil obtained from the sample (PKS and EFB) might be a potentially valuable source as a renewable fuel and for the usage of chemical feed stocks.

ABSTRAK

Penghasilan minyak bio daripada bahan buangan kelapa sawit (tandan kosong dan isirong) diuji menggunakan kaedah *pyrolysis* di dalam makmal. Untuk tujuan ini, persediaan bahan (sampel) menjadi parameter dalam kajian ini. Komposisi bahan juga dianalisis dalam kajian ini, kadar pengeluaran minyak bio yang tertinggi untuk isirong adalah pada suhu 400 °C dengan ukuran sample kurang 5 mm manakala untuk uji kaji terhadap tandan kosong, kadar pengeluaran tertinggi adalah pada ukuran sampel 5mm-10mm panjang. Karakter minyak bio yang terhasil dalam situasi ini diuji menggunakan *FTIR*, *GCMS* serta *TGA*. *FTIR* digunakan untuk mengetahui kumpulan berfungsi manakala *GCMS* digunakan untuk mengetahui komponen kimia didalam produk. *TGA* dalam kajian ini digunakan untuk mengetahui takat meruap sampel, baki abu dan kandungan kelembapan sampel. Dalam analisis ini, minyak bio yang diperolehi daripada sampel (Tandan kosong dan Isirong) berpotensi untuk menjadi sumber bahan api ganti dan juga untuk stok kekal bahan kimia.

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LIST OF SYMBOLS

g	-	gram
s	-	second
min	-	minute
⁰ C	-	degree celcius
Mol/g	-	mole per gram
Wt%	-	weight percentage
mm	-	millimeter
Mg/l	-	milligram per liter
Kcal	-	kilo kalori
mL/min	-	milliliter per minute
in	-	inch
bar	-	pressure
μL	-	microlitre
LHV	-	low heating value
HHV	-	high heating value
Mj/Kg	-	mega joule per kilogram
Dp	-	diameter particle
L	-	length
PKS	-	palm kernel shell
EFB	-	empty fruit bunch

TGA	-	thermo gravimetric analyser
GC-MS	-	gas chromatography mass spectrometer
FTIR	-	fourier transform infrared spectroscopic
μm	-	micrometre

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Renewable energy is growing importance and it relate to the environment and security of energy supply. Ever since environmental concerns over the fossil fuels with respect to their limited reserves emerged, interest in environmental – friendly alternative energy resources that can reduce dependency on fossil fuels has been growing.

With respect to the global issues of sustainable energy and reduction in greenhouse gases, biomass is getting increased attention as a potential source of renewable energy. According to the World Energy Assessment report, 80% of the worlds primary energy consumption is contributed by fossil fuel, 14% by renewable energy (out of which biomass contributes 9.5%) and 6% by nuclear energy (Rogner *et*, 2002)

Particularly, among a number of alternative energy resources, biomass which consists mainly of cellulose, hemicelluloses, and lignin, is seen to play an important role both as chemical feedstock and as alternative to fossil fuels. Due to these facts, investigations on thermo – chemical and bio - chemical conversion technologies for biomass utilization have been conducted world wide.

Over the last two decades, a special attention has been paid to the conversion of residual biomass and renewable materials into bio fuel. (Garcia – Perez *et al*, 2002) Since researches and works in relation to biomass have recently been focused on the use of biomass as a fuel.

1.2 Palm Oil Waste

The oil palm industry in Malaysia started 80 years ago in a modest way. Today it is the largest in agricultural plantation sector, exceeding rubber plantation by more than double in area planted. In term of hectare, the total area under oil palm cultivation is over 2.65 million hectares, producing over 8 million tonnes of oil annually. The oil consists of only 10 % of the total biomes produced in the plantation. The reminder consists of huge amount of lignocellulose materials such as oil palm frond, trunk, and empty fruit bunches. The projection figure of these residues is as follows:

- i. 7.0 million tonnes of oil palm trunks
- ii. 26.2 million tonnes of oil palm fronds
- iii. 23% of empty fruit bunch (EFB) per tonne of the fresh fruit bunch (FFB) processed in oil palm mill.

These figures depend on life span of oil palm tree that is due for replanting after about 20 -25 years old. Extracted from the paper entitle Fibre processing technology fractionation proms to produce fibrous strands from oil palm residues (Mahmudin, 2004).

Malaysia therefore has a great potential in turning its abundant supply of oil palm industry by –product into value added product. Under the present scenario, Malaysia can no longer remain idle and complacent in its positions as the top grower and supplier of palm oil. In view escalating challenge posed by other oil producing

countries, Malaysia has to change its objective of being a world producer of palm oil to amongst others a leader in converting biomass waste into value added products. Oil from the palm oil fruit can produce bio diesel but not for the waste product like, empty fruit bunch, fibre, mesocarp, oil palm trunk fibre and palm kernel. All waste usually dismiss without knowing their potential for bio – oil production.

1.3 Problem Statement

For the production of bio-oil, EFB and PKS has been pyrolyzed in a laboratory scale electrical tubular furnace with stainless steel (316) reactor as shown in Figure 1.1. The main of pyrolysis characteristics components, hemicelluloses, cellulose and lignin of biomass were analysis using FTIR and GC. Lignin was more difficult to decompose, so high temperature needed to crack the bonding via endothermic process. The sample (EFB and PKS) shredded and sieved to get the smallest particle size range.

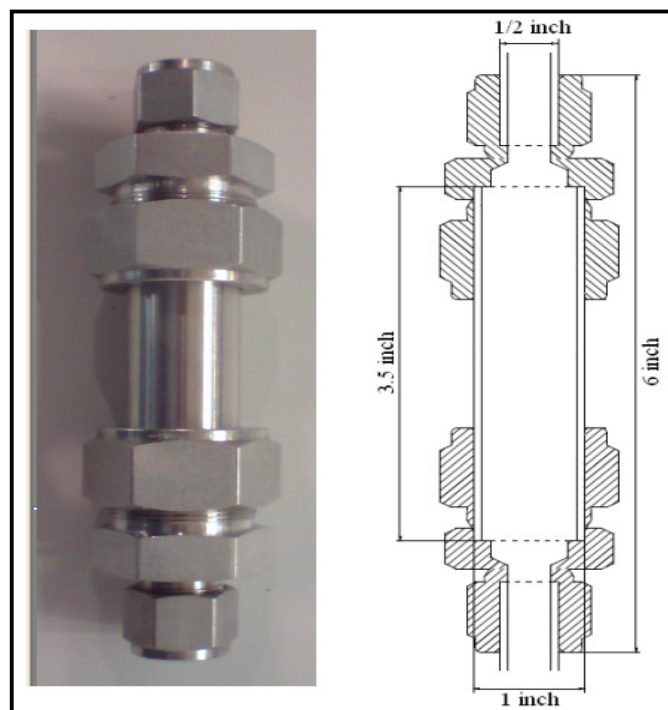


Figure 1.1: Stainless Steel Reactor

The effect of the sample preparation of the sample analyzed to study at which particle size the higher product will produce. Beside that, the retention time will also analyze when the experiment started and at the time of the production produce.

Particle size range (diameter) $d_p < 5$ mm, which is the suitable range of the analysis for PKS while for EFB particle size range (Length) $L < 1$ mm, 1-5 mm, 5 -10 mm and $L > 10$ mm. At different particle size, different amount of bio oil produce; depend on their cutting size.

To get high yields of bio oil production, sample preparation (size of particle) is the way can be achieve. It is to ensure the sample could react at optimum process temperature and minimise their exposure to the intermediate (lower) temperatures that favour formation of charcoal.

Besides that, temperature also play important role in production of bio oil. Hence temperature $400\text{ }^{\circ}\text{C}$ have been choose in this experiment to get high yield of bio oil instead charcoal.

1.4 Objectives Research

The objective of this research is to study:-

- i) The sample preparation for empty fruit bunch (EFB) and palm kernel shell (PKS) for bio-oil production.
- ii) The characteristic of bio-oil for empty fruit bunch and palm kernel shell.

1.5 Scope of Works

On this research, there are focuses on two main scopes:

- i. Palm kernel Shell
 - a. Sample preparation for temperature effect to a pyrolysis process of palm kernel shell with constant overall particle size of 1mm diameter.
 - b. The temperature effect study had been conducted at moderate temperature 200 °C, 300 °C, 400 °C, 500 °C and 600 °C.
- ii. Empty Fruit Bunch
 - a. Sample preparation for particle size effect to a pyrolysis of empty fruit bunch was investigated with constant temperature of 400 °C.
 - b. The study had been conducted for sample length of $L < 1\text{mm}$, 1-5 mm, 5-10mm, $L > 10\text{ mm}$.

1.6 Rationale and Significance

The rationale of this research is empty fruit bunch is the most waste in palm oil industry compared to others waste. It has a potential for the production of bio oil. The empty fruit bunch fibre (EFB) was identified as the first of the series of standard on oil palm fibres because of logistic reasons.

EFB has the highest fibre yield and is the only material commercially utilised for fibre extraction but there are good potentials for the exploitation of the other two materials (oil palm fronds and trunks). Besides that the characteristic of EFB fibres are clean, biodegradable and compatible than many other fibres from others.

PKS Kernel shell is a fibrous material which is easily handled in bulk directly from the product line in the palm oil manufacturing and to the end use. It consists of fractions of the nut shell. Large and small shell fractions are mixed with dust-like fractions and small fibres. Moisture content is low compared to the other biomass residues. Further more, the production of bio oil can generate the energy by further process. Hence in the end of the experiment, we can find the suitable particle size that can produce the highest value of bio oil.

CHAPTER 2

LITERATURE REVIEW

2.1 Background of Biomass

Biomass energy currently contributes 9–13% of the global energy supply accounting for 45 ± 10 EJ per year or up to 14% (Thomas et.al., 2003). Biomass energy includes both traditional uses such as a ring for cooking and heating and modern uses such as producing electricity and steam, and liquid bio-fuels (Hisyam, 2006). Biomass, in the energy production industry, refers to living and recently dead biological material which can be used as fuel or for industrial production.

Most commonly, biomass refers to plant matter grown for use as bio-fuel, but it also includes plant or animal matter used for production of fibres, chemicals or heat (Volk et.al, 2006). Biomass may also include biodegradable wastes that can be burnt as fuel. It excludes organic material which has been transformed by geological processes into substances such as coal or petroleum.

The term "biomass" encompasses diverse fuels derived from timber, agriculture and food processing wastes or from fuel crops that are specifically grown or reserved for electricity generation. Biomass is a material that contain carbon and hydrogen compound which can be form as a fuel or for production.

2.2 Types of Biomass

Biomass can be split into two distinct categories first is waste biomass and second is energy crops. Waste biomass is forestry residue, sewage waste, animal farming waste, organic municipal solid waste (MSW), slaughterhouse and fishery. For energy crops is short rotation coppice (SRC), miscanthus, woodchips, straw, residue from fruit processing (e.g. stones, husks) and others. Furthermore, biomass is referring to recently or deadly organic material and it useful in providing renewable source of fixed carbon.

Each will give different range of product either gas, solid or liquid. Physical conversion involved densification; more easily handled such as briquettes particles, palletized fuel and fuel logs. These involve extrusion process of biomass particles with or without binder at higher pressure and later carbonized to obtain charcoal material (Ani, 2006).

2.3 Biomass in Malaysia

Today, about 80% of Malaysia's total population lives in Peninsular Malaysia, the hub of the country's economic activities. Like many other developing countries, energy has been the prime contributor towards the rapid growth of Malaysia's economy. Malaysia is looking forward in industrial and development sector that need sustainable energy resources.

The available fossil fuels sources now only can survive for another 20 to 30 years (Hisyam, 2006). Malaysia is the largest producer and exporter of palm oil in the world, accounting for 30% of the world's traded edible oils & fats supply. 3.88 million hectares of land in Malaysia is under oil palm cultivation producing 14 million tonnes of palm oil in 2004 (Jessada, 2007).

Currently, Malaysia faced this scenario; the growing demand of technology and becoming developed nation by 2020, limited fossil fuel reserves, only 30–40 years and net oil importer from 2040 and the major challenges to overcome this problem; fuel security, electricity sales price, renewable energy power purchasing agreement, financing assistance, lack of promotion, conventional vs. renewable energy power plant and subsidy for conventional energy (Mohamed et.al., 2006).

Malaysia government need fully supports re-biomass based power generation through various initiative and promotion program such as biogen since biomass resources is big potential for Biomass Power Co-Generation and beside that Malaysia can develop and expend the market profitability through new technology and lower production cost to overcome the challenges (Hamdan, 2004).

Energy has contributed significantly towards the rapid growth of the Malaysia economy. Energy supply infrastructure needs to be more continuously developed and being very capital intensive, it will impose tremendous pressure on the depleting resources. Successful implementation of this biomass utilization would provide the oil palm industry with an additional substantial income of over RM30 billion per year in addition to the current RM15 billion per year from the oil and its derivatives (speech from Minister of Primary Industries, Dato' Seri Dr. Lim Keng Yaik, launched the Biomass Technology Centre (BTC) and the Farm Mechanization Centre (FMC) of the Malaysian Palm Oil Board (MPOB) in Bangi, Selangor, 5 February 2002).

Furthermore, compare to the cost of fossil fuels that increasing by year in Malaysia, there is a strong reason to produce gases using cheaper raw material. As biomass is created by plants absorbing CO₂ from the air, releasing this CO₂ when oxidizing biomass does not lead to a net increase in greenhouse gas (GHG) emissions if biomass is produced in a sustainable manner. Carbon dioxide has been targeted as the greenhouse gas.

Other gases, such as CFC's and nitrous oxide offer far larger positive feedbacks to global warming than carbon dioxide. The concern, however, is over the extreme levels of carbon dioxide concentration in the atmosphere, which adds immensely to the problem of global warming. Considering this factor, offsets such as this would help to significantly reduce atmospheric concentrations of carbon dioxide. This burning biomass can be used a conventional power plant (that is, one with a conventional boiler to produce steam that runs through a turbine) built solely for the biomass is another option.

For the past decade Malaysia is dealing with serious environmental problem. The serious pollutions that occur in Malaysia are air pollution that which mainly causes by transportation and factories. Disadvantages of fossil fuel derived transportation fuels beside others problem such as greenhouse gas emissions, pollution, resource depletion, unbalanced supply demand relations, are strongly reduced or even absent with bio transportation fuels.

2.4 Biomass Technologies

There are some technologies that can convert biomass into energy and higher product value. This can be classified as show in Figure 2.1. The biochemical process leads to anaerobic digestion to produce gases and alcohol fermentation to produce ethanol. For non-biological process, it refer to thermal conversion which the main of it is converting solid waste into energy and by-product; gasification, combustion, pyrolysis and liquefaction.

Each will give different range of product either gas, solid or liquid. Physical conversion involved densification; more easily handled such as briquettes particles, palletized fuel and fuel logs. These involve extrusion process of biomass particles with or without binder at higher pressure and later carbonized to obtain charcoal material (Ani, 2006).

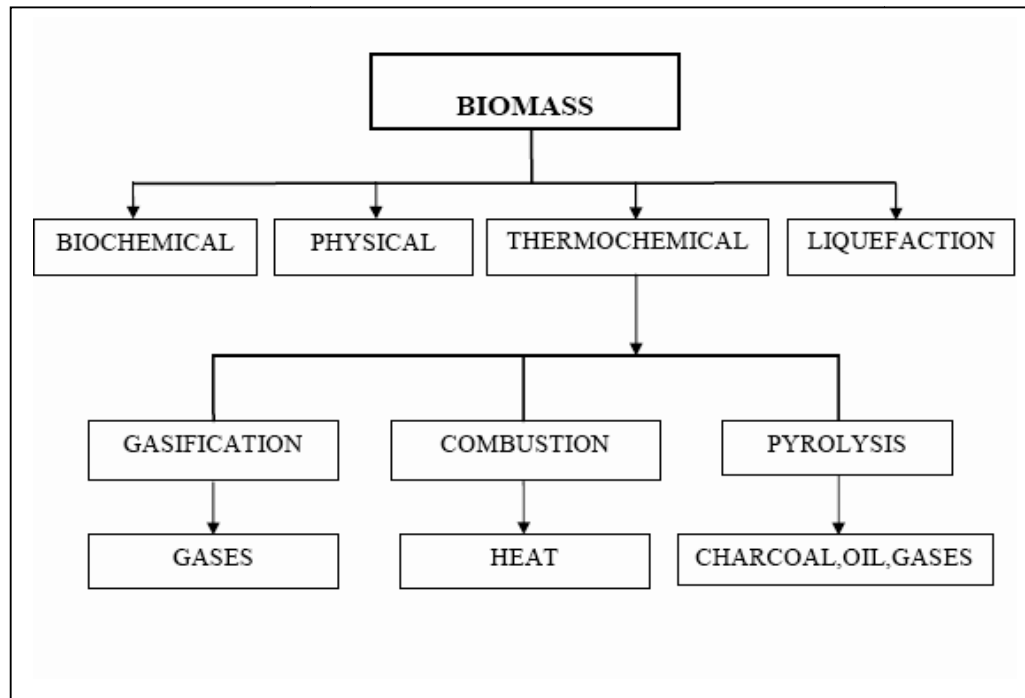


Figure 2.1: The Main Type and Process of Biomass (Ani 2006)

2.4.1 Gasification Process

Gasification is a process that converts carbonaceous materials, such as coal, petroleum, biofuel, or biomass, into carbon monoxide and hydrogen by reacting the raw material at high temperatures with a controlled amount of oxygen and/or steam. The resulting gas mixture is called synthesis gas or syngas and is itself a fuel. Gasification is a method for extracting energy from many different types of organic materials.

There are four types of gasifier are currently available for commercial use now days counter-current fixed bed, co-current fixed bed, fluidized bed and entrained flow. The advantage of gasification is that the synthesis gas is a better fuel than original solid biomass, and can stored and transport more easily. The syngas is potentially more efficient than direct combustion of the original fuel because it can be combusted at higher temperatures or even in fuel cells, so that the thermodynamic upper limit to the efficiency defined by Carnot's rule is higher or not applicable.